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A BRIEF HISTORY OF SYSTEM SAFETY
AND ITS CURRENT STATUS IN AIR FORCE
ACQUISITION PROGRAMS

THESIS

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AFIT/GLM/LSM/88S-71

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

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Master of Science in Acquisition Logistics

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Captain, USAF

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Notation

AD - Armament Division

AFB - Air Force Base

AFISC - Air Force Inspection and Safety Center

AFIT - Air Force Institute of Technology

AFLC - Air Force Logistics Command

AFR - Air Force Regulation

AFSC - Air Force Systems Command

ANG - Air National Guard

ASD - Aeronautical Systems Division

BMD - Ballistic Missile Division

CCB - Configuration Control Board

CDRL - Contract Data Requirements List

DOD - Department of Defense

DTIC - Defense Technical Information Center

ECP - Engineering Change Proposal

ESD - Electronic Systems Division

ICBM - Intercontinental Ballistic Missile

MA - Managing Activity

MIL-STD - Military Standard

NASA - National Aeronautics and Space Administration

NNMSB - Nonnuclear Munitions Safety Board

OHA - Operating Hazard Analysis

O&SHA - Operating and Support Hazard Analysis

PHA - Preliminary Hazard Analysis

PMP - Program Management Plan

SD - Space Division

SHA - System Hazard Analysis

SOW - Statement of Work

SPO - System Program Office

SSHA - Subsystem Hazard Analysis

SSPP - System Safety Program Plan

TAC - Tactical Air Command

TDY - Temporary Duty

TEMP - Test and Evaluation Master Plan

USAF - United States Air Force

USAFR - United States Air Force Reserve

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Abstract

The purpose of this study was to explore the origin, evolution, and present status of system safety in the Air Force Systems Command (AFSC) acquisition process. The study had five objectives: 1) Determine the origin of system safety. 2) Describe the discipline of system safety. 3) Explain how system safety has evolved. 4) Determine the current effectiveness of system safety. 5) Determine what the future holds for system safety.

The study found that system safety was first applied to the Minuteman Missile Program in 1962. Since then, its scope has expanded and its governing documents have further specified responsibilities. The new AFSC Form 180 is required by the AFSC Supplement to AFR 800-16 to be filled out and signed by program managers. This form shows the residual risk associated with each hazard identified in a system and documents the program manager's acceptance of the residual risk. Thirty-five system safety personnel and thirty-five program management and engineering personnel from the four AFSC Product Divisions were interviewed to determine the current effectiveness of system safety. The study shows that system safety is considered an important part of the acquisition process (over)

and cost-effective. There is a need for improved software system safety in the future along with a continuing need for personnel.

Among recommendations of the study were soliciting emphasis on system safety from higher management levels, including system safety in introductory acquisition management courses, and development of a computerized lessons learned data base by the Air Force Inspection and Safety Center.

A BRIEF HISTORY OF SYSTEM SAFETY AND ITS CURRENT STATUS IN AIR FORCE ACQUISITION PROGRAMS

I. Introduction

General Issue

The discipline of system safety is becoming increasingly important in the weapon system acquisition process. Since its reputed beginning in the ballistic missile programs of the 1960s, system safety has spread throughout the Department of Defense and the world of defense contractors. The increasing complexity and the tremendous increase in the cost of weapon systems gave rise to the popularity of system safety. By designing safety into the systems from the beginning, life cycle costs can be reduced along with increased system reliability (7:9). System safety is currently receiving high-level interest in an extremely dynamic acquisition process (12).

Specific Problem

The exact beginning of system safety is unclear. It is generally believed to have started in the Air Force ballistic missile programs of the 1960s (11,12). Since its inception, system safety has grown to include not only missiles, but most major weapon systems and subsystems (2:1). This thesis chronicles the evolution of system safety in the Air Force from its first application to the status of its current level of utilization. It also draws conclusions on the current perceptions and effectiveness of Air Force system safety programs based on interviews of system safety and program management personnel.

Investigative Questions

Looking at the history of system safety in the Air Force and its effectiveness involved answering some questions about its origin and the discipline itself. The research objectives were attained by answering the research questions below each objective.

1) To determine the origin of system safety:
   a) When did a formal system safety program first appear?
   b) Who originated it?
   c) If the first system safety program appeared in an organization other than the Air Force, when did the Air Force adopt the innovation?
2) To understand the discipline:
   a) What constitutes system safety?
   b) How is it applied in an Air Force acquisition program?

3) To explain the evolution of system safety:

   a) How has it changed over the years?

   b) How have the governing regulations changed over time?

   c) What are the benefits of an effective system safety program?

4) To determine if system safety is currently effective:

   a) Do program management officials value the support of their system safety managers?

   b) Do system safety managers see themselves as being worthwhile to the programs they support?

   c) Are system safety managers qualified and able to perform their jobs?

5) To discover what may happen in the future:

   a) Is system safety still developing?

   b) What are some current issues/trends?

By exploring the answers to these questions, the development of the discipline, the process itself, and the effectiveness of system safety became clear.

Scope

The discipline of system safety can currently be found throughout the Department of Defense (DOD) and in many defense contractors' management structures (3). To effectively research the history of system safety, it was necessary to restrict the scope of the research. It was not feasible to look at how system safety is applied in each military service and contractor. It was, however, possible to look at the evolution of the discipline itself as one area, and the evolution and application of system safety to Air Force acquisition programs as another.

Other Safety Concerns. It is important to understand that system safety is only one area in the safety arena. Other areas include flight safety and ground safety. Flight safety is concerned with airborne systems already in operation (17). Ground safety relates mainly to personnel safety in an occupational surrounding, and includes industrial safety (15). System safety deals with the design of systems during the acquisition process. System safety does, however, use lessons learned from both of these other areas in order to prevent hazards from being repeated in future designs (3).

Discipline of System Safety. As a discipline, system safety transcends the boundaries of the military services and defense contractors. When a development in system safety is made in one organization, it will eventually impact the application of the discipline in all organizations. For this reason, this thesis considers the general evolution of the discipline of system safety to be a superset of the evolution of system safety in the Air

Force. The evolution and significant developments of system safety as a whole was one area of research.

System Safety in the Air Force. To effectively explore how system safety is applied in an acquisition process, it was necessary to focus attention on one particular area. This thesis concentrates on how system safety is applied during an Air Force Systems Command acquisition program. In addition, the evolution of the regulations which govern the Air Force system safety program are discussed rather than reviewing the regulations unique to all of the other services.

Looking at the general development of the discipline of system safety and then describing the specific aspects of the system safety process in the Air Force effectively limited the scope of this thesis.

Background

The formal discipline of system safety has been around for over 20 years (12, 12:1-6). During this time, many changes have taken place in system safety. There are many informational "how to" books and guides to aid system safety managers and engineers; however, few people outside of the discipline itself have a real understanding of what system safety is.

The Air Force system safety program is directed by DOD Instruction 5000.36, 14 April 1986 (2:1). There are many regulations and guidelines that are used to manage and implement system safety programs in the Air Force. The two major documents used in managing Air Force system safety programs are AFR 800-16 and MIL-STD-882B.

AFR 800-16, USAF System Safety Programs. The policy on Air Force system safety programs is contained in AFR 800-16. Its purpose and intent are best explained in the regulation itself:

> This regulation explains policy on system safety programs and makes Air Force activities responsible for carrying out that policy throughout the system life cycle. It applies to all commands, the US Air Force Reserve (USAFR) and Air National Guard (ANG), and implements DOD Instruction 5000.36, 14 April 1986. It requires each major command, separate operating agency, and direct reporting unit (MAJCOM, SOA, DRU) to set up and conduct or support an effective USAF system safety program (2:1).

MIL-STD-882B, System Safety Program Requirements. While AFR 800-16 states that system safety programs must be developed, MIL-STD-882B explains how to develop system safety programs. It is broken up into different tasks to be performed by the contractor. By selectively including only the tasks necessary in a contract, the system safety program is tailored to each system (6:1-2). By tailoring the system safety requirements to each system, money is saved by not requiring the contractor to perform unneeded tasks.

MIL-STD-882B provides the following overview of its overall purpose:

> This standard provides uniform requirements for developing and implementing a system safety program of sufficient comprehensiveness to identify the

> hazards of a system and to impose design requirements and management controls to prevent mishaps by eliminating hazards or reducing the associated risk to a level acceptable to the managing activity (6:1).

There are, of course, many other regulations and guidelines that govern the Air Force system safety program, however, the two above have the most significant impact. While these two documents contain information on system safety, other steps were needed to answer the research questions.

II. Methodology

Method of Research

The research design I used to answer my research questions was that of a descriptive study and structured interviews. The information I gathered pertains to the evolution, contents, and effectiveness of the system safety discipline. I also studied the application of system safety in the Air Force Systems Command acquisition process. To effectively gather the information I needed, several different steps were taken.

My information was gathered by interviewing system safety managers and program management officials, as well as by reviewing literature on system safety.

Interviews. My interviews were done in person when possible. Because of the scarcity of TDY funds, personnel stationed at locations other than Wright-Patterson AFB were interviewed by telephone. In all cases, the interviews were conducted using the structured interview questions contained in Appendices A and B. This ensured that the same questions were asked every individual.

By interviewing system safety managers, I determined how system safety programs are applied in an acquisition program. They also provided valuable information on recent changes within the discipline and on the benefits of an effective system safety program. System safety managers that have many years of experience were an excellent source of information on how the discipline has evolved and spread over the years. The main thrust of the interviews was to determine how the system safety managers perceive their contribution to acquisition programs and to determine their working relationships with program management personnel. Air Force personnel I interviewed included safety personnel from Aeronautical Systems Division (ASD), Electronic Systems Division (ESD), Space Division (SD), and Armament Division(AD).

Interviews with program management officials gave me a more objective view on the effectiveness of system safety in the acquisition process. Their perspectives as managers and engineers presented the perceived benefits of system safety on their programs. I interviewed program managers and engineers of acquisition programs at the four AFSC product divisions. These individuals gave me an understanding of what kind of emphasis is currently being placed on system safety and what some of the current issues are.

Review of Documentation. Reviewing documentation on system safety not only provided information on the contents of the discipline, it also explained the origin and evolution of system safety. Several sources were obtained from the Defense Technical Information Center

(DTIC). These consisted of theses, technical reports, and papers done by military students.

<u>Measures</u>

Table I shows the relationship between the research objectives, research questions, and the interview questions. The interview questions are designed to answer research questions, however, many research questions were answered using documentation rather than interviews. Research objectives 1, 2, and 3 were all attained through searching documentation and informational interviews with system safety personnel. The next chapter explains the discipline of system safety and its benefits.

Table I

Relationship Between Research Objectives, Research Questions, and Interview Questions

Program Management Interview Question	Answers Research Question	Answers Research Objective
1	info	info
2	info	info
3	4a	4
4	4a	4
5	4a	4
6	4a	4
7	4a	4
8	5a, 5b	5
9	5b	5

System Safety Mgr Interview Question	Answers Research Question	Answers Research Objective
1	info	info
2	4c	4
3	4c	4
4	4c	4
5	info	info
6	info	info
7	4a	4
8	4b	4
9	5a, 5b	5

III. System Safety Program Process and Benefits

Responsibilities of Air Force System Safety Managers

The tasks and responsibilities of system safety managers are too varied and too numerous to describe them all. A few of the major duties are discussed below.

Review Contractual Documents and Plans. The system safety manager will make inputs to the program management plan (PMP), the statement of work (SOW), the specifications, the contract data requirements list (CDRL), and others (12). By doing so, the manager may be tasking the contractor to do millions of dollars of work for the Air Force. One of the options is to require the contractor to perform hazard analyses in the statement of work (6:202-1 - 205-1).

Hazard Analyses. The purpose of hazard analyses is to identify hazards and show how they will be eliminated or controlled (6:101-2). The four types of hazard analyses are: preliminary hazard analysis (PHA), subsystem hazard analysis (SSHA), system hazard analysis (SHA), and operational and support hazard analysis (O&SHA).

Preliminary Hazard Analysis. The PHA is performed early in the life cycle of a system to determine which general areas may pose potential problems later in the system's development (6:202-1). It is a broad analysis and is required as a minimum on all system safety programs (2:4).

<u>Subsystem Hazard Analysis</u>. The SSHA is performed on the subsystems of a system to identify and control hazards in each subsystem which may degrade safety or end in a failure of a system (6:203-1). Examples of subsystems are engines, landing gear, etc.

<u>Fault Tree Analysis (FTA)</u>. This is a top-down analysis which starts with an undesired event and continues through the system to determine the event or combination of events that could cause the undesired event (5:14).

<u>Sneak Circuit Analysis (SCA)</u>. An SCA is an analysis that identifies latent (sneak) circuits and conditions that may inhibit desired functions or cause undesired functions without a component failure. It can be conducted on either software or hardware (5:14).

<u>System Hazard Analysis</u>. The SHA is performed on the entire system with particular emphasis on the subsystem interfaces. It will also include a look at human errors which could result in mishaps (6:204-1).

<u>Operating and Support Hazard Analysis</u>. The O&SHA is performed to identify and control hazards associated with the use of the system throughout its life cycle (6:205-1). This analysis will generate many

cautions and warnings on the hardware itself or in technical data.

Order of Precedence. In all of the hazard analyses, an order of precedence is followed when determining how to handle the hazards identified. Obviously, the best solution to a hazard is to design the hazard out of the system. In many cases, unfortunately, this solution is not feasible. The elimination of the hazard may be too costly or necessary to the operation of the system (e.g., fuel in an aircraft). The next step is to use a safety device to interlock or guard the hazard. If this is also unfeasible, a warning device, such as a bell or horn, will be used to call attention to the hazard. When all of these actions are impractical, the last resort is to use special procedures, such as caution and warning notes, to avoid the hazard (6:6).

Advisor to Program Manager on System Safety. The system safety manager is the person the program manager will contact if there is a question about system safety (12). There should be a direct line of communication between the program manager and the system safety manager.

It is important to realize that the system safety manager is trying to minimize the risk of mishaps associated with a system, however, it is the responsibility of the program manager to accept any risk associated with the system (11). If the system safety manager identifies a hazard and thinks it should be eliminated or controlled, the final decision is up the program manager's. He may decide to accept the risk against the recommendation of the system safety manager. The system safety manager must ensure that the risk the program manager is assuming is fully understood by the program manager (11).

<u>Key Coordination Point in System Program Office (SPO)</u>. The system safety manager is required to coordinate on nearly all program documentation (11). Of particular importance are the test and evaluation master plan (TEMP) and the engineering change proposals (ECPs) (12). The TEMP is important because a flight safety certification must be developed before an aircraft or aircraft subsystem can be flown. The system safety manager is an important part of this process (11).

ECPs are changes to a system's design. The system safety manager must monitor these to assess their impact on the safety of the system. If there is an impact to the safety of the system, additional analysis may be necessary, or the system safety manager may not approve the change. Being a member of the Configuration Control Board (CCB), which reviews and adopts or rejects ECPs, the system safety manager may vote against an ECP. In such cases, it again becomes the program manager's responsibility to make the final decision.

Monitor Contractors' Performance. The system safety manager monitors the contractors' performance in the system safety area to ensure they are fulfilling their contractual obligations (12). If they are not, the system safety manager must work with the program manager and the contracting people to correct any deficiencies. It is also the system safety manager's responsibility to make sure the contractor is providing meaningful information that is effective. It is possible that the contractor is submitting information that is not applicable to his program. For example, a contractor on on aircraft program submitted quantified hazard analyses with probabilities that were, in fact, generated by another contractor a different program (11). Again, if the information isn't meaningful, the system safety manager must help to correct the situation.

These are only a few of the responsibilities of the system safety manager. If a system safety manager is effective in his job, the program manager and the program will benefit in many ways.

Benefits of an Effective System Safety Program

The benefits of system safety are easily understood. An effective system safety program will save money and improve combat capability, however, its nearly impossible to quantify (12, 13:1-1-1-7).

Reduce Life Cycle Cost. By integrating an effective system safety program at a program's inception, it will have more than paid for itself by the end of the system's life cycle.

The cost of design changes rises dramatically as the acquisition process matures. By the time a system is in full production, a design change will cost 54 times as much as it would have during the conceptual phase (12). By identifying hazards as early as possible, future changes are reduced, thereby saving money.

The elimination or control of hazards early in the life cycle not only saves money, it will also save resources. If the number of damaged or destroyed systems is reduced by an effective system safety program, the savings is very high. With the increasing cost of weapons systems, this potential savings continues to grow (13:1-2 - 1-7).

Human resources may also be saved by an effective system safety program. If the number of aircraft lost due to preventable mishaps is lowered, a reduction in airman fatalities is almost certain to follow. Thus, system safety can save money and lives.

Increase Combat Capability. The conservation of resources, both men and equipment, that can be saved by an effective system safety program directly impacts combat capability. By not losing aircraft and pilots, the number of aircraft the Air Force can have in the air is increased.

The downtime that is avoided by identifying hazards early in the system's life cycle will also increase combat capability. The fewer retrofits a system undergoes, the more time it is available to perform its mission.

Quantifying the Benefits of System Safety. The nature of system safety makes it nearly impossible to measure its effectiveness. The payoff for an effective system safety program is a mishap not occurring. How can an event not occurring be measured? As Miller and Frola state, "It is like trying to measure how much illness has been avoided by proper nutrition" (13:1-4). If a design change is made due to a hazard being identified through hazard analysis, it's impossible to actually prove that the design change actually prevented an accident (12). For this reason, system safety is sometimes faced with trying to justify its existence. Top level management support is essential to the development of an effective system safety program.

Success Stories. To illustrate the possible benefits of system safety, two examples of system safety impacts to recent acquisition programs are presented below:

> During a modification to the B-52, a system safety engineer noted that if the front lugs of the Air-Launched Cruise Missile attachment retracted but the

rear ones did not, parts of the pylon would tear from the wing and, together with the missile, would inflict severe structural damage to the wing and possibly the horizontal stabilizer. The system was redesigned (13:1-5).

A safety engineer found in the PAVE LOW helicopter system that loss of voltage in a radar circuit would cause a command to the aircraft to fly at zero altitude with no warning to the pilot. He also checked with personnel on the RF-4C and A-7D programs, knowing they used the same system. All aircraft were quickly prohibited from flying certain low-level missions until the systems were corrected (13:1-5).

Now that the discipline itself has been explained, the history of system safety can be explored.

IV. Brief History of System Safety

The concept of safety has always existed in the acquisition and operation of weapon systems. Weapon systems are intended to perform their missions without inflicting casualties and/or damage to innocent parties or equipment. This resulted in systems being acquired that had a reasonably good chance of completing a mission. When a mishap occurred, however, an investigation was conducted to determine the cause of the accident(9:23). If the cause was serious and it was determined that it was likely to happen again in the future, a change was implemented to redesign the system. This "fly-fix-fly" attitude was expensive due to the costs of retrofitting systems that were already operational. During the course of retrofitting an entire system, extensive downtime was experienced which negatively impacted the combat capability of the system. Also, in some cases the design change could take years to be completed in all operational systems. This was not only an inconvenience, but there was always the risk of a repeat mishap occurring while the change was being implemented. As technology improved and the cost of developing and producing weapon systems skyrocketed, it became apparent that there had to be a more efficient way of doing business(13:1-6).

First Formal System Safety Program

Ironically, though the first system safety program to be developed was in the Air Force, it was not applied to an aircraft development program. The Ballistic Missile Division (BMD) was involved in the operational testing and site activation of the first intercontinental ballistic missiles (ICBM) in the late 1950's and early 1960's. During the course of this testing, BMD experienced numerous mishaps. Five missile silos were destroyed costing millions of dollars. At least five people were also killed as a result of mishaps(14:1-1). One particular incident that created a great deal of concern was an inadvertent launch at Cape Canaveral in 1959. A short in a battery was found to have caused the missile to launch accidently. Fortunately, the missile was able to be destroyed before it was over Cuba (10). This all added up to a very low launch-success rate and many schedule delays. During the investigations of these mishaps, it was determined that a large percentage of the causes were direct results of design deficiencies, poor operational planning, and ill-conceived management decisions. With this discovery came the realization that the key to preventing mishaps lay in the design and production of the missile rather than correcting the design after it fails (14:1-1).

In April 1962, BMD produced the exhibit "System Safety Engineering for the development of Air Force Ballistic Missiles." This document outlined the system safety requirements for the associated contracts on the Minuteman Missile program. Thus was born the first formal system safety effort(9:29). This document was revised in September 1963 and became MIL-S-38130, "Military Specification-General Requirement for Safety Engineering of Systems and Associated Subsystems and Equipment." In June 1966, this specification was furthur revised and became MIL-S-38130A. Finally, in July 1969, another revision was made and the specification became MIL-STD-882. "System Safety Program for Systems and Associated Subsystems and Equipment." MIL-STD-882 then became a mandatory requirement on all DOD procured products and systems(16:12).

Evolution of MIL-STD-882

The stated purpose of MIL-STD-882 is as follows:

> The purpose of this standard is to provide uniform requirements and criteria for establishing and implementing system safety programs and to provide guidelines for preparing system safety program plans (SSPP). (4:1)

The standard spells out the requirements of system safety in acquisition programs. It establishes four levels of hazard severity ranging from negligible to catastrophic. The levels were:

Category I -- negligible

Category II -- marginal

Category III -- critical

Category IV -- catastrophic

General guidelines for system safety requirements during the different phases of the acquisition cycle are outlined. It includes the order of precedence for overcoming hazards described in the previous chapter. The four major types of hazard analysis (PHA, SSHA, SHA, OHA) are described. An appendix outlines a proposed format for a system safety program plan to be submitted by contractors. The approved SSPP would then become the basis for contractual compliance (4:3-16).

MIL-STD-882A. MIL-STD-882A states its purpose as:

> This standard provides uniform requirements for developing and implementing a system safety program of sufficient comprehensiveness to identify the hazards of a system and to ensure that adequate measures are taken to eliminate or control the hazards (5:1).

The first readily apparent difference in this version is the emphasis in the purpose on identifying and then eliminating or contolling hazards rather than just establishing a system safety program. It includes a section on the responsibilities of the managing activity (MA) and the contractor. MIL-STD-882A also adds a section on hazard probabilities which denote the likelihood of hazards occurring. These are combined with the hazard levels to determine the criticality of hazards. These probabilities are:

Descriptive Words	Category
Frequent	A
Reasonably probable	B
Occasional	C
Remote	D
Extremely improbable	E
Impossible	F

The hazard severity levels of MIL-STD-882 were also reversed so that a category I hazard became catastrophic, category II - critical, category III - marginal, and category IV -negligible. Fault tree analysis is also discussed for the first time (5:3-16).

MIL-STD-882B. The purpose of MIL-STD-882B reads as follows:

> This standard provides uniform requirements for developing and implementing a system safety program of sufficient comprehensiveness to identify the hazards of a system and to impose design requirements and management controls to prevent mishaps by eliminating hazards or reducing the associated risk to a level acceptable to the managing activity (MA). (6:1)

The purpose statement of MIL-STD-882B has now shifted from eliminating or controlling hazards to eliminating hazards or reducing risk to acceptable levels. This recognizes that no system is ever completely free of risk. The format of this standard is almost entirely different than previous versions. It contains task descriptions that can be selectively applied to acquisition programs. This allows the MA to tailor the system safety program to each system. The task descriptions are divided int. two general sections: Section 100, Program Management and Control and Section 200, Design and Evaluation. The standard also contains two appendices that provide guidance and rationale for selecting tasks to be applied to different systems. One significant task that is included in MIL-STD-882B calls for the performance of software safety hazard analysis (6:1 - 212-1).

Evolution of AFR 800-16, USAF System Safety Programs

AFR 800-16 was first published 6 June 1979. It explains the USAF policy for system safety. It superseded AFR 127-8, dated 19 April 1976. This change removed the regulation from the 127-safety series of regulations and placed it in the 800-acquisition series. This helped place emphasis on the integration of system safety into the design and development of weapon systems. It also required the implementing command to formally document the acceptance of risk associated with identified hazards. This version addressed system safety requirements to off-the-shelf procurement items, but only for Air Force Logistics Command (AFLC) programs. It also requires the identification and maintenance of safety critical items listings; these being items that can fail and create a potential for major injury or damage (1:1 - 6).

AFR 800-16, 21 August 1987. This regulation is currently in effect. The major implication of this revision is the requirement for all implementing and using commands to publish supplements to the basic regulation. It also requires independent safety assessments at major program milestones, and requires Headquarters USAF to formally accept the residual risk for major programs. It removes all references to safety critical items, and clarifies and expands the responsibilities of the using commands. This revision adds a separate section on off-the-shelf procurements. This section adds responsibilities to the implementing commands, rather than just to AFLC programs. It also adds the requirement for supporting commands to develop hazardous materials programs to meet the rising need for such emphasis (2:1 -12).

AFSC Supplement, AFR 800-16, 9 February 1988. While this supplement isn't another revision of AFR 800-16 as such, it does modify the regulation consistent with the scope of this thesis. Its purpose is to further define AFSC's responsibilities in system safety programs. It stresses preventing hazards from being designed into systems developed, acquired, or modified by AFSC. It also emphasizes accountability for residual risk. The supplement introduces AFSC Form 180, Residual Risk Assessment/Acceptance. This form is to be used to identify the risk associated with each hazard identified within the system. Each Form 180 is then signed by the chief engineer and the program manager (3:1 - 2). This ensures that program management is fully aware of the risk existing in the system (8:6 - 10). The supplement contains instructions on filling out Form 180 and provides a completed example (3:3 - 4).

The development of system safety has been a constant process. To determine the present status and mood of system safety, interviews were conducted. The results of these interviews are contained in the next chapter.

V. Data Analysis and Findings

Data Analysis

This chapter presents the results of the data collected by the structured interviews to further satisfy the research objectives presented in Chapter one. A total of seventy interviews were conducted. Thirty-five system safety personnel were interviewed, along with thirty-five program management/engineering personnel. These seventy individuals are members of Armament Division, Space Division, Electronic Systems Division, and Aeronautical Systems Division of Air Force Systems Command.

Responses are presented from each product division and then an overall summary. Each question from both structured interviews will be addressed separately. Questions one through six of the system safety personnel interview were used to determine the education, experience, training, and current responsibilities of the interviewees. Questions seven through nine will be discussed from the standpoint of a majority opinion and a minority opinion. Questions one through four and question nine of the program management/engineering personnel interview were used to determine knowledge and awareness of system safety and current responsibilities. Questions five through eight will again be discussed using the majority/minority opinion format. It should be noted that because of simple yes/no responses and some respondents giving more than one comment to some questions, in some cases the number of respondents do not seem to add up correctly. This, however, is not the case.

Interviewees were assured that their responses would be confidential. For this reason, most of the statements quoted in the findings section will remain anonymous.

Findings

Of the seventy interviewees, six were from Electronic Systems Division, ten from Armament Division, twelve from Space Division, and forty-two from Aeronautical Systems Division. Half of each division's interviewees were from system safety, the others were from program management/engineering. The large number of Aeronautical Systems Division is due to their proximity and the large number of system safety personnel.

Interview Results

Electronic Systems Division -- System Safety Personnel.

Question One. What is your current duty title? One of the three respondents include system safety in their duty title. The Director of Safety has the responsibility for all areas of safety, including system safety, as does the Deputy Director of Safety.

Question Two. What is your educational background? All three persons have undergraduate degrees in engineering and graduate degrees in management-related fields.

Question Three. How much experience do you have in system safety? All three interviewees have three or more years of system safety experience.

Question Four. What system safety training have you had? The system safety manager course, formerly taught by the University of Southern California (currently taught by the University of Washington) was attended by all three individuals. Two had additional training from other courses.

Question Five. What programs do you currently have system safety responsibility for? Since the system safety function at ESD acts as a staff function, the interviewees had system safety responsibilities for all of the ESD programs. This results in the personnel being responsible for more than one program.

Question Six. What office is your reporting official located in? This question was designed to see if the system safety personnel had a direct line of communication to the program managers. As a staff office, they do have direct lines of communication to the ESD program managers.

Question seven. How would you describe your working relationship with the program office personnel you work with?

Majority Opinion. All three individuals conveyed some kind of concern with their relationships with program office personnel. One response was, "it varies from excellent to non-existent" depending on the program in question. The overall feeling was that their system safety programs are given a low priority. One unidentified program manager was quoted as saying, "these are ground systems, they don't have hazards." As an aside, shortly after the program manager made this statement, one of the systems was damaged by fire.

Minority Opinion. The minority opinion was stated in the above quote referencing excellent support on some programs.

Question Eight. What are your views on the impact your system safety program has on your acquisition programs?

Majority Opinion. All of the interviewees believe that their efforts are very effective when they are allowed to do their jobs. However, all three mentioned that in many cases their inputs are eliminated due to funding cuts. All think that their impact is somewhat restricted.

Minority Opinion. No minority opinion was expressed.

Question Nine. What trends are developing in the discipline of system safety?

Majority Opinion. All three respondents feel that the recent budget cuts and the future budget cuts have and will result in more streamlined system safety programs.

Minority Opinion. While all of the interviewees believe the future holds reduced system safety efforts, two of the three anticipate an increased emphasis being placed on system safety. While this seems contradictory, it is not necessarily so. While the system safety efforts may be reduced in scope, the remaining program may be considered more important. One respondent attributes this increase in emphasis on system safety to the new ESD Vice Commander.

Electronic System Division -- Program Management Personnel.

Question One. What is your current duty title? Two of the three respondents were program managers. The third was an engineer.

Question Two. What acquisition programs are you responsible for? All three individuals identified themselves with one specific program, however, in one case the individual was responsible for many projects under the main program.

<u>Question Three</u>. How familiar are you with the discipline of system safety? All three admitted that they knew little about system safety.

<u>Question Four</u>. Do you know who has system safety responsibility for your programs? Two of the three interviewees did know who their programs' system safety managers were. One stated that he had no idea.

<u>Question Five</u>. How do you view the discipline of system safety?

<u>Majority Opinion</u>. All three of the interviewees stated that system safety is an important consideration in an acquisition process. Its value to electronics integration was mentioned by two of the interviewees. One stated that the higher the value of the equipment in question, the more important system safety becomes.

<u>Minority Opinion</u>. No minority opinion was expressed.

<u>Question Six</u>. Does system safety contribute to your programs?

<u>Majority Opinion</u>. Two of the three respondents felt very sure that system safety is positively contributing to their programs.

Minority Opinion. One interviewee said that he was neutral on the subject; that he couldn't say that system safety contributed to, or hindered, his program.

Question Seven. Is system safety cost-effective?

Majority Opinion. All three individuals think that system safety is cost-effective, but all had qualifiers. One stressed that it's most cost-effective when done during the design phase, not when it's done after the system is operational. Two stated that it's cost-effective if the system safety program is tailored to each specific program, thereby eliminating unnecessary costs.

Minority Opinion. No minority opinion was expressed.

Question Eight. How could system safety be improved to enhance its value to your programs?

Majority Opinion. All three respondents presented different ideas to the question. No majority opinion was expressed.

Minority opinion. One individual thinks system safety is effective the way it is and that the contractors are also applying system safety effectively. Another respondent urges more involvement earlier in the acquisition process to the advantage of the low cost of design changes. The last respondent was more specific: he wants an alternative to Halon fire suppression systems because of the difficulty in supporting them.

Question Nine. Have you received any guidance from higher headquarters concerning system safety? Only one of the three interviewees recalls having seen any correspondence from higher headquarters concerning system safety. He couldn't remember what it addressed, but said it came from TAC Headquarters.

Armament Division -- System Safety Personnel.

Question One. What is your current duty title? Four of the five interviewees include engineer in their duty title. The fifth includes system safety.

Question Two. What is your educational background? Four of the five interviewees have undergraduate degrees in engineering. Three of the respondents also have graduate degrees in engineering or management.

Question Three. How much experience do you have in system safety? The least experienced of the individuals has five years of experience. Three of the five have over twenty years of experience in system safety. The mean number of years experience in this sample is 15 years. The value of this experience to the system safety effort at Armament Division is obvious.

Question Four. What system safety training have you had? All five respondents have completed both the system safety manager course and the fault tree analysis course offered by the University of Washington.

Question Five. What programs do you currently have system safety responsibilities for? The AD System Safety Directorate acts as a staff office. Thus, all five respondents cover numerous acquisition programs.

Question Six. What office is your reporting official located in? All five persons interviewed report to people in the Deputy for Safety.

Question Seven. How would you describe your working relationship with the program office personnel you work with?

Majority Opinion. Four of the five respondents stated that they have excellent working relationships with the SPO personnel at AD. Two of these four credit their good rapport to the fact that in many cases the system safety personnel provide the corporate memory for the programs. Another says SPOs are responsive to the system safety inputs because of their position as a staff office.

Minority Opinion. One individual states that, historically, the working relationship between system safety and the SPOs hasn't been very good. He states that the SPOs are usually so intent on fielding a system, they lose their insight into system safety requirements.

Question Eight. What are your views on the impact your system safety program has on your acquisition programs?

Majority Opinion. Four of the five people interviewed consider system safety to have a major impact on acquisition programs. Two of the respondents credit this impact to the fact that most AD programs must be certified by the Nonnuclear Munitions Safety Board (NNMSB) before they can be fielded. This enables the system safety manager to ensure his requirements are met in order to pass the NNMSB review. Two other respondents mentioned that it was tougher to make contractors pay attention to safety than the Air Force.

Minority Opinion. One individual stated that system safety had some impact on programs, but it ususally takes a catastrophic event to get attention. He mentioned that he thought the Challenger mishap increased the acceptance of system safety.

Question Nine. What trends are developing in the discipline of system safety?

Majority Opinion. Three of the respondents believe that system safety is getting more and more emphasis in the acquisition business. Two of them credit the Challenger mishap for this increased emphasis.

Minority Opinion. Two interviewees mentioned the increasing need for software system safety. As more and more systems are controlled by computer software, it becomes more and more important to ensure that the software cannot cause inadvertent actions resulting in mishaps. Another individual claims technology is advancing faster than system safety's ability to analyze it.

Armament Division -- Program Management Personnel.

Question One. What is your current duty title? Three of the interviewees were engineers. The other two were program managers.

Question Two. What acquisition programs are you responsible for? Three of the five respondents work on only one program. The other two are responsible for more than one program.

Question Three. How familiar are you with the discipline of system safety? All five people interviewed were aware of system safety, but none felt they were very familiar with its specific requirements.

Question Four. Do you know who has system safety responsibility for your programs? All five respondents knew who had system safety responsibility for their programs.

Question Five. How do you view the discipline of system safety?

Majority Opinion. Four of the five interviewees stated that system safety was an integral part of the acquisition process. Two stated that the value of system safety depends greatly on the weapon system itself. The more complex the system, the more valuable system safety becomes.

Minority Opinion. One respondent considers system safety to be merely another requirement to be added to a program. Another individual thinks system safety should be integrated with the engineering community in order to better perform their duties.

Question Six. Does system safety contribute to your programs?

Majority Opinion. Three of the five interviewees were very positive in their comments on system safety's contributions to their programs.

Minority Opinion. Two individuals stated that at times system safety adds requirements to programs that aren't necessary. They said that adhering to all of the requirements of a system safety program is sometimes just not feasible. Another stated that system safety does not contribute to his program at all.

Question Seven. Is system safety cost-effective?

Majority Opinion. Three of the five respondents consider system safety to be cost-effective.

Two mentioned that if system safety saves just one life, it more than makes up for any and all costs associated with it.

Minority Opinion. Two individuals consider system safety to be cost-effective, but not efficient. They state that in many instances some system safety requirements are unnecessary and a waste of money. One other considers all system safety to be a waste because engineering covers the safety aspect.

Question Eight. How could system safety be improved to enhance its value to your programs?

Majority Opinion. Two respondents think that system safety would benefit from having more personnel. The increasing complexity of weapon systems has increased the need for more system safety, but there hasn't been an increase in manpower.

Minority Opinion. Two respondents didn't have any ideas on how to improve system safety. Another suggested that system safety should be integrated with engineering. This would increase their visibility and effectiveness.

Question Nine. Have you received and guidance from higher headquarters concerning system safety? None of the interviewees have seen any correspondance concerning system safety.

Space Division -- System Safety Personnel.

Question One. What is your current duty title? All six of the people interviewed include system safety in their duty titles. Only one included the term engineer.

Question Two. What is your educational background? Four of the interviewees have bachelor's degrees in engineering. Two have advanced degrees in engineering, one also holds a Ph.D.

Question Three. How much experience do you have in system safety? Five of the six interviewees have less that five years of experience. One, however, has been in system safety since its inception, some twenty-eight years.

Question Four. What system safety training have you had? Five of the six respondents have attended the system safety manager course taught by the University of Washington. All six have attended a local SD training course.

Question Five. What programs do you currently have system safety responsibility for? Because of the function of a staff office, all six persons interviewed are responsible for more than one program.

Question Six. What office is your reporting official located in? All the individuals reported to others within the Directorate of Safety.

Question Seven. How would you describe your working relationship with the program office personnel you work with?

Majority Opinion. Four of the six people interviewed stated that their working relationship with SPO personnel is pretty good. They all mentioned that support varies greatly from program to program. Some program managers are very receptive to the system safety managers, while others tend to ignore them completely.

Minority Opinion. Two of the respondents stated that their relationship with the SPO personnel is not very good. Safety tends to be a very low priority. Both, however, state that things are improving immensely and the SPOs are placing more emphasis on system safety.

Question Eight. What are your views on the impact your system safety program has on your acquisition programs?

Majority Opinion. All six respondents believe they are having a good impact on acquisition programs. Two of them state that impact varies from program to program, depending on the support of the SPOs.

Minority Opinion. One person mentions that at times SPOs don't pay enough attention to system safety in the beginning of the program. When it becomes time to prepare to launch the system, they suddenly become system safety conscious. This late action results in many systems needing waivers in order to launch.

Question Nine. What trends are developing in the discipline of system safety?

Majority Opinion. Three of the six people interviewed see an increasing emphasis on system safety. Two of them credit the Challenger disaster for the increase in emphasis.

Minority Opinion. There were many interesting trends mentioned by individuals. One respondent brought up a new way of contracting. The Air Force is paying a contractor only for "successful launches." He says this will increase the emphasis on system safety at the contractor's facility because the contractor can't afford to miss launches or lose a launch vehicle without reimbursement. Another stated that the emphasis in the future is going to be on in-orbit safety. There are many different things in orbit now and the increasing amounts of satellites and space debris is really complicating matters. Another trend identified is the fact that now most DOD payloads are now launched from expendable launch vehicles rather than the space shuttle.

Space Division -- Program Management Personnel.

Question One. What is your current duty title? Four of the six interviewees were program management individuals. The other two were engineers.

Question Two. What acquisition programs are you responsible for? Three of the respondents worked on only one program. The other three worked on more than one program.

Question Three. How familiar are you with the discipline of system safety? Five of the six interviewees state that they are somewhat familiar with system safety. The other one stated that he is very familiar with the discipline.

Question Four. Do you know who has system safety responsibility for your programs? All six are aware of who their system safety representative is.

Question Five. How do you view the discipline of system safety?

Majority Opinion. Five of the six people interviewed look at system safety as being a very important part of the acquisition process. Two of the five think that it needs even more emphasis than it is currently getting. Another stressed that system safety representatives need to use more common sense and not just add all requirements to all programs.

Minority Opinion. The other respondent didn't think that system safety applies to his program and didn't offer an opinion on the discipline.

Question Six. Does system safety contribute to your programs?

Majority Opinion. Five interviewees feel strongly that system safety is a valuable contributor to their programs.

Minority Opinion. The remaining respondent said that system safety only occasionally contributes to his program and right now it is not contributing.

Question Seven. Is system safety cost-effective?

Majority Opinion. Five of the six interviewees stated that system safety is cost-effective. Two of the five stress that when system safety is incorporated very early in the acquisition process, the cost-effectiveness rises dramatically. This is because the later design changes are made, the more money they cost.

Minority Opinion. One respondent stated that system safety representatives just "stick requirements in contracts without knowing the program." This results in unnecessary costs making system safety not cost-effective.

Question Eight. How could system safety be improved to enhance its value to your programs?

Majority Opinion. Three of the six think that system safety personnel need to get more involved with the programs. By doing this, tailoring system safety requirements to each program would be easier. This would result in fewer unnecessary costs.

Minority Opinion. One respondent thinks that training contractors on the contents of MIL-STD-882B would enhance the value of system safety. Two others had no suggestions for improvement.

Question Nine. Have you received any guidance from higher headquarters concerning system safety? Two interviewees recall seeing a letter from SD/CC directing an independent assessment for safety inspections be done on certain programs before operation. This came after the space shuttle disaster. The other four respondents don't remember any kind of correspondence concerning system safety.

Aeronautical Systems Division -- System Safety Personnel.

Question One. What is your current duty title? Eighteen of twenty-one people interviewed termed themselves as system safety managers. Three stated they were system safety engineers.

Question Two. What is your educational background? Thirteen of the twenty-one interviewees have undergraduate degrees in some kind of engineering. Eleven of the twenty-one have master's degrees. Only one has a master's degree in engineering.

Question Three. How much experience do you have in system safety? Seven of the twenty-one respondents have five years experience or more. The mean years of experience is 4.4 years.

Question Four. What system safety training have you had? All but one of the people interviewed have attended the system safety manager course now offered by the University of Washington. Fifteen have also attended the fault tree analysis course also taught at the University of Washington. Only one of the twenty-one respondents has not received any formal system safety training.

Question Five. What programs do you currently have system safety responsibility for? Twelve of the twenty-one interviewees work on only one major weapon system. The remaining nine have responsibility for more than one weapon system. However, most major weapon systems have many projects related to their development.

Question Six. What office is your reporting official located in? Eight of the nine three-letter safety directors interviewed report directly to the two-letter directors. The one exception reports to a three-letter. The remaining twelve interviewees report to either the three-letter safety directors, or the Chief of ASD Safety.

Question Seven. How would you describe your working relationship with the program office personnel you work with?

Majority Opinion. Eighteen of the twenty-one people interviewed stated their relationships with the SPO personnel are pretty good to excellent. However, ten of the eighteen said that their relationships do have instances when they have some problems getting SPO personnel to listen to them and keep them informed on program developments.

Minority Opinion. Three of the twenty-one stated that they have trouble communicating with the program managers. They believe that system safety has a very low priority and program managers tend to ignore them.

Question Eight. What are your views on the impact your system safety program has on your acquisition programs?

Majority Opinion. Sixteen of the twenty-one interviewees said that they were having a good impact on acquisition programs. Three of the sixteen mentioned that they have had "success stories," instances when they actually caused changes in design to be made. One stated that the SPO director, a brigadier general, was system safety's biggest supporter.

Minority Opinion. Five of the respondents believe that they were having little impact on their acquisition programs. One stated that the little impact he is having is diminishing because safety is the first thing to be cut in times of budget cuts. Three of the five claim that system safety has a "bad name." This results in the system safety personnel fighting to get attention and trying to justify their requirements. One respondent went so far as to suggest that system safety may not even be necessary.

Question Nine. What trends are developing in the discipline of system safety?

Majority Opinion. Three major trends were identified. Seven interviewees expressed concern over the issue of software system safety. The need is growing, but the ability to do software system safety is still developing. Seven respondents also stated that there is a trend towards system safety emphasizing the management aspects more than developing the technical expertise to perform system safety engineering. Six of the people interviewed cited an increasing shortage of manpower. Four of these people specifically mentioned the loss of pilots. One reason for this is the recent change in the certification process for the 27XX career field. This makes it very difficult for rated supplement positions. This results in a loss of operational expertise.

Minority Opinion. Three of the twenty-one interviewees did not identify any trends. Two respondents mentioned a swing toward accountability. They believe the new AFSC Form 180, as required by the new AFSC Supplement to AFR 800-16, is a way to force the program managers to accept residual risk associated with their systems. This also removes responsibility from the system safety representative. One other respondent stated that there is an increasing emphasis on performance of weapon systems. This results in shortcuts being taken which, in turn, increases risk. One other respondent simply stated that there is diminishing respect for system safety.

Aeronautical Systems Division -- Program Management Personnel.

Question One. What is your current duty title? Eleven of the people interviewed are engineers. The other ten are program management individuals.

Question Two. What acquisition programs are you responsible for? Sixteen of the twenty-one people interviewed work on only one program. The remaining five have multiple responsibilities.

Question Three. How familiar are you with the discipline of system safety? Eleven of the twenty-one interviewees stated they were not very familiar with system safety. Eight respondents said they were somewhat familiar with the discipline. The remaining two believe they are very familiar with system safety.

Question Four. Do you know who has system safety responsibility for your programs? Only one respondent did not know who had system safety responsibility for his program. The remaining twenty knew their system safety representative.

Question Five. How do you view the discipline of system safety?

Majority Opinion. Eighteen of the twenty-one people interviewed term system safety as important or very important. Four of these respondents, however, qualified their answers. Two of them stated that many times system safety adds requirements that are unnecessary and a waste of time and money. Two others believe that the discipline itself is disorganized and difficult to understand.

Minority Opinion. Three of the twenty-one interviewees don't think that system safety is very important. One termed system safety as a "watchdog agency" that merely duplicates engineering work.

Question Six. Does system safety contribute to your programs?

Majority Opinion. Of the twenty-one people interviewed, eighteen said that system safety does contribute to their programs. Two of the eighteen did state, however, that sometimes system safety representatives add unnecessary requirements. This reduces its effectiveness.

Minority Opinion. Three respondents don't think system safety is contributing to their programs. Two view system safety only as a square-filler. The third respondent stated that while system safety is currently not contributing to his program, he would not be without it.

Question Seven. Is system safety cost-effective?

Majority Opinion. Fifteen of the twenty-one interviewees consider system safety to be cost-effective. Three said lives are more valuable than any costs associated with system safety. One other stated that while he thinks system safety is cost-effective, it isn't efficient because many of the costs are not necessary. Another stressed that the earlier system safety is incorporated in a program, the more cost-effective it is because of the increasing cost of changing designs.

Minority Opinion. One respondent doesn't think system safety is cost-effective. Two interviewees say that because of the difficulty in measuring the effectiveness of system safety, its cost-effectiveness can't be measured. Two other respondents said that because of the nature of their programs, they can't see how much money is being spent on system safety. The last interviewee thinks that it would probably be cheaper to ignore system safety.

Question Eight. How could system safety be improved to enhance its value to your programs?

Majority Opinion. Two major areas of possible improvement for system safety were suggested. Four respondents said that system safety needs more manpower to be effective. They are spread too thin to be as effective as possible. Four other respondents believe that system safety needs some kind of computerized data base of lessons learned. This would help prevent the same design mistakes from being repeated.

Minority Opinion. Six respondents had no ideas on improving system safety. Three of the twenty-one interviewees stated that system safety would be more effective if it was incorporated into the engineering function. This would reduce duplication of effort and present a united front. Two interviewees said that system safety needs more authority. Their rank structure isn't enough to be taken seriously. One respondent thinks the system safety discipline needs more structure. He suggests they adopt some sort of checklist approach to identifying hazards. Another states simply that the system safety personnel need to get more involved and get to know the weapon systems better.

Question Nine. Have you received any guidance from higher headquarters concerning system safety? Nineteen of the twenty-one people interviewed have not seen any kind of correspondence from higher headquarters concerning system safety. One respondent stated he saw some kind of policy letter on safety a few years ago. Another stated that his new program director issued a letter emphasizing system safety as soon as he arrived.

Overall Results -- System Safety Personnel.

Question One. What is your current duty title? Twenty-five of the thirty-five system safety personnel interviewed consider themselves system safety managers. Eight are system safety engineers, and two use only "safety" in their duty titles.

Question Two. What is your educational background? Twenty-four of the thirty-five interviewees have undergraduate engineering degrees. Nineteen have master's degrees, one has a Ph.D.

Question Three. How much experience do you have in system safety? Six of the thirty-five interviewees have more than ten years of experience in system safety. The mean level of experience is 6.2 years.

Question Four. What system safety training have you had? Thirty-three of the thirty-five people interviewed have attended the system safety manager course taught by the University of Washington. Twenty have also attended the fault tree analysis course offered by the same school. Only two out of the thirty-five have not received any formal system safety training.

Question Five. What programs do you currently have system safety responsibility for? Twenty-three of the thirty-five respondents are responsible for more than one program. Twelve work on only one major weapon system.

Question Six. What office is your reporting official located in? Sixteen of the thirty-five people interviewed are members of staff offices. Ten of the respondents report to three-letter system safety directors. Eight of nine co-located system safety directors report to the two-letter program directors. Only one reports to the three-letter level.

Question Seven. How would you describe your working relationship with the program office personnel you work with?

Majority Opinion. Twenty-six of the thirty-five interviewees said they have good or excellent working relationships with SPO personnel. Fourteen of these admit that the relationships vary from person to person. Four others credit their value as corporate memory to the SPOs as the reason for the favorable relationships.

Minority Opinion. Nine of the thirty-five respondents stated their relationships with the SPO personnel were not very good. They believe they are a low priority to the SPOs. Two of these, however, think their relationships are improving.

Question Eight. What are your views on the impact your system safety program has on your acquisition programs?

Majority Opinion. Of the thirty-five system safety personnel interviewed, twenty-nine of them stated that they are having a good impact on their acquisition programs. Three still think they are somewhat restricted because of the negative attitude SPOs have against system safety. Two others said they are having an overall good impact but that the affects vary from program to program.

Minority Opinion. Six of the thirty-five interviewees said they are having little impact on their programs. Three stated that system safety has a "bad name" and that many of their efforts are ignored. One respondent thinks the emphasis on system safety is diminishing. Another claims it takes a catastrophe to shift attention to system safety.

Question Nine. What trends are developing in the discipline of system safety?

Majority Opinion. Eight of the thirty-five respondents think there is an increasing emphasis on system safety. Four of these credit the Challenger disaster for this trend. Eight others stated there is an ever-increasing need for software system safety as weapon systems become more complex. Six respondents see an increased emphasis on the management aspects of system safety, away from the technical, analytical aspects. Five others said decreasing manpower is the current major trend in system safety.

Minority Opinion. Three of the thirty-five interviewees did not identify any trends. Three respondents think the future will bring more streamlined system safety programs because of the emphasis on reducing costs. Two others think technology is advancing so rapidly that system safety is lagging behind in its ability to perform hazard analysis on it. Two interviewees view the new AFSC Form 180 as an emphasis on accountability and getting the program managers more involved in system safety. Finally, two other interviewees see an increasing emphasis on the performance of weapon systems. One sees this as creating more emphasis on system safety at the contractor's program office, while the other thinks it may cause shortcuts to be taken, decreasing overall system safety.

Overall Results -- Program Management Personnel.

Question One. What is your current duty title? Eighteen of the thirty-five people interviewed are program managers. The other seventeen are engineers.

Question Two. What acquisition programs are you responsible for? Twenty-five of the thirty-five interviewees are only responsible for one program. The remaining ten work on more than one program.

Question Three. How familiar are you with the discipline of system safety? Of the thirty-five people interviewed, nineteen stated they are not very familiar with system safety. Thirteen said they are somewhat familiar with the discipline. The remaining three said they are very familiar with system safety.

Question Four. Do you know who has system safety responsibility for your programs? Only two of the thirty-five people interviewed did not know who their system safety representative is.

Question Five. How do you view the discipline of system safety?

Majority Opinion. Thirty of the thirty-five interviewees consider system safety to be an important part of an acquisition program. Three of these said its importance varies according to a system's value and complexity. The higher the value and complexity, the more important system safety becomes, and vice versa.

Three of these thirty also believe that, at times, unnecessary system safety requirements are added to contracts. Two others said that there needs to be a greater emphasis on system safety.

Minority Opinion. Only four of the thirty-five interviewees do not think system safety is an important part of an acquisition program. One interviewee did not offer an opinion.

Question Six. Does system safety contribute to your programs?

Majority Opinion. Twenty-nine of the thirty-five respondents stated that system safety contributes to their programs. Four of these, however, said that system safety does sometimes add unnecessary requirements to contracts which hinder its overall contribution to a program.

Minority Opinion. Six respondents do not think system safety contributes to their acquisition programs. Two consider system safety to be merely a "square-filler." One other stated that while system safety is currently not contributing to his program, he would not be without it. The remaining individual was completely ambivalent towards system safety.

Question Seven. Is system safety cost-effective?

Majority Opinion. Of the thirty-five people interviewed, twenty-seven think system safety is cost-effective. Five of these stress the need to tailor system safety requirements to each program to eliminate unnecessary costs, thereby raising cost-effectiveness. Five others stated that if the incorporation of system safety saves just one life, it is cost-effective. Four of the twenty-seven emphasize the early incorporation of system safety because it's cheaper to change paper than metal.

Minority Opinion. Four of the thirty-five respondents do not think system safety is cost-effective. Four others don't know if it's cost-effective. Two of these can't see the money spent on system safety because of the program structure, and the other two said that the benefits of system safety can't really be measured, making it impossible to determine cost-effectiveness.

Question Eight. How could system safety be changed to enhance its value to your programs?

Majority Opinion. Six of the thirty-five interviewees think system safety needs more manpower to effectively do their job. In a related vein, four respondents stressed that system safety representatives need to get more involved with the acquisition programs. This would be easier if there were more system safety personnel. Four other respondents said that system safety would be more effective if it was incorporated into the engineering structure. Another four respondents suggested the development of a computerized data base of lessons learned to prevent earlier design inadequacies from being repeated.

Minority Opinion. Eleven respondents had no suggestions on improving system safety. Two of the thirty-five interviewees said system safety's rank structure doesn't provide them with enough authority to be truly effective. Another stressed earlier involvement in the acquisition process. One individual said that the system safety organization needs more structure. Another thinks training contractors on the requirements of MIL-STD-882B would be beneficial. Finally, one individual specifically wants an alternative to halon fire suppression systems to increase supportability.

Question Nine. Have you received any guidance from higher headquarters concerning system safety? Only five of the thirty-five interviewees recall ever seeing correspondence from higher headquarters concerning system safety. Thirty said they have never seen such correspondence.

Other Significant Findings

Because of the nature of the open-ended question used in the interviews, the researcher received many comments that really didn't pertain directly to the questions.

Some of the more significant comments included information about the Challenger disaster, career progression in system safety, and system safety training.

Impact of the Challenger Disaster. There were varying opinions on how the explosion of the space shuttle affected the image of system safety. Six people think that the incident caused an increased emphasis on performing system safety during the acquisition process. Four others mentioned that they didn't think the Challenger had any impact at all on system safety emphasis. Two of them, however, stated that after the mishap the National Aeronautics and Space Administration (NASA) hired a large number of system safety personnel. This resulted in many individuals leaving the military and contractors and joining NASA. Perhaps the most interesting information came from Mr. Roger Lockwood, a co-founder of the system safety discipline. Using NASA's hazard probabilities, he published a paper predicting a catastrophic mishap on the shuttle's twenty-fifth launch. The Challenger disaster occurred on the twenty-fourth launch (10).

Career Progression. While four of the program management personnel mentioned that system safety would benefit by having additional manpower, four system safety personnel stated that they have trouble getting personnel into system safety because there is no room for career advancement. A major reason military shun entering the system safety field is the historically low promotion rates. Unfortunately, no actual statistics were found.

Training. Two of the program management personnel suggested that system safety should be addressed in the introductory acquisition classes taught at each product division. This would at least promote awareness. On the other side of the coin, six system safety personnel volunteered that the required system safety manager course they attended was almost worthless. They believe that the instruction received had little to do with what their duties actually are.

Now that the data has been presented, some conclusions and recommendations can be made.

VI. Conclusions and Recommendations

Introduction

This chapter contains the conclusions and recommendations of this research effort. There were five objectives to the research. First, it attempted to determine the origin of system safety. Second, it sought to understand the discipline itself. The third objective was to explain the evolution of system safety. The fourth objective of the research was to determine the current effectiveness of system safety. Finally, the research attempted to discover what the future holds for system safety. A summary of findings will be related to the thirteen research questions and relevant conclusions will be drawn. In addition, this final chapter will include recommendations for improving system safety and suggested areas for further study and research.

Research Questions

The first eight research questions were answered through documentation search and informational interviews with system safety personnel. The detailed results of these questions are contained in Chapters III and IV.

Question 1a. This question attempted to find when and on what program system safety was first applied. As mentioned in Chapter IV, the first system safety program was applied on the Minuteman Missile Program in 1962.

Question 1b. The discipline of system safety was first developed by the Ballistic Missile Division of the Air Force. During the researcher's interviews, Mr. Roger Lockwood, one of the founders of system safety was interviewed.

Question 1c. If system safety was developed in an organization other than the Air Force, the researcher wanted to determine when the Air Force adopted the discipline. Since it was developed in the Air Force, the question became unnecessary.

Question 2a. This question dealt with the discipline itself. It attempted to determine what system safety is and what its purpose is in an acquisition program. It is a process by which hazards are identified and eliminated or controlled in a weapon system. Ideally, this takes place during system design. Chapter III contains a more detailed discussion of system safety.

Question 2b. This question sought to describe how system safety is applied to acquisition programs. As stated above, it is best to implement a system safety program as early as possible during a system's life cycle. In AFSC, system safety representatives review contractual documentation to ensure system safety requirements are met. These individuals also coordinate on program documentation to assess impact on the safety of the system. In addition to this, they must monitor contractor tasks to ensure quality products. While the system safety representatives are the focal point for system safety concerns, the program manager is still responsible for accepting any risk associated with the system.

Question 3a. This question served to see how the process of system safety has evolved through the years. It began by being applied to only one Air Force program. It is now appicable to all DOD acquisition programs including the purchase of off-the-shelf equipment. More details are contained in Chapter IV.

Question 3b. To see how the DOD and Air Force positions on system safety have changed through the years, the researcher looked at how the main governing documents have changed since the origin of system safety. Responsibilities have expanded, and many new techniques have been introduced. The AFSC Form 180 is now required by the AFSC Supplement to AFR 800-16. This form is to be filled out for every hazard identified in a system. The program manager then signs each form to accept the residual risk associated with each hazard. This appears to the researcher to be a tool to relieve the system safety community from any responsibility should a hazard cause a mishap in the future. Admittedly, the program manager has always had final responsibility for a fielded system. However, it does give the appearance of protecting the system safety representative. On the other hand, the AFSC Form 180 will also force the program manager to get involved with the system safety program. It ensures that the program manager knows all the hazards in the system. If the program manager does not want to accept the risk associated with a hazard, he can get involved with the system safety manager to eliminate or control the risk to an acceptable level.

Question 3c. This question was designed to see what system safety can do for an acquisition program. An effective system safety program can conserve both equipment and human resources by preventing mishaps. It can also increase combat capability. By changing designs before systems are operational, downtime due to retrofits will be decreeased. System safety can also save systems from being destroyed due to catastrophic mishaps. This keeps more systems operational. Two actual examples of the benefits of system safety are provided in Chapter III.

Question 4a. This question was designed to determine how program management personnel view system safety. Six interview questions were used to help find the answer: question seven on the system safety personnel interview, and questions three, four, five, six, and seven on the program management personnel interview. Based on the responses to these questions, it is evident that program management personnel value the contributions that system safety makes to their programs. Almost three-fourths of the system safety personnel interviewed stated that they had good to excellent working relationships with the SPOs. Over eighty-five percent of the program management personnel interviewed consider system safety to be an important part of an acquisition program. Only two of the thirty-five SPO personnel interviewed do not know who their system safety representative is. It is acknowledged that some program personnel don't think that system safety is worthwhile. There are two reasons that may explain this without reflecting badly on the discipline: 1) the respondent's program may be such that the impact of system safety is minimal (i.e., small program, little development), and 2) the system safety representative may be negligent in his duties or have personality conflicts with the SPO personnel. Dissenting opinions aside, the vast majority of program management personnel interviewed consider system safety to be a valuable contributor to their programs. The challenge is to overcome the negative attitudes toward system safety.

Question 4b. This question was designed to determine the attitude of system safety personnel as to their perceived worth to their acquisition programs. Based on the responses received to question eight of the system safety personnel interview, system safety managers consider themselves to be valuable contributors to their respective acquisition programs. Over eighty-two percent of the system safety personnel interviewed consider their efforts are having a positive impact on their programs. This may also impact job satisfaction, though that area is beyond the scope of this thesis.

Question 4c. This question was designed to see if the program management personnel are receiving system safety support from personnel that know their responsibilities and have expertise to carry them out. Questions two, three, and four were used to answer this question. Almost seventy percent of the system safety personnel interviewed have engineering degrees. Over half have advanced degrees. The system safety manager course, now offered by the University of Washington, has been attended by over ninety-four percent of the respondents, with fifty-seven percent having attended the fault tree analysis course at the same school. The average experience level of the thirty-five system safety personnel interviewed was 6.2 years. Based on these facts, it is apparent that system safety personnel are both qualified and able to perform their jobs.

Question 5a. The purpose of this question was to determine if system safety has become stagnant or if it is still a dynamic field. The responses to question nine of the system safety personnel interview and question eight of the program management personnel interview indicate that system safety still has plenty of developing to do in the future. Twenty-two percent of the system safety representatives interviewed think the emphasis on system safety is increasing. This in itself will ensure that system safety keeps on developing. The fact that only five of the thirty-five program management personnel interviewed have seen correspondence from higher headquarters concerning system safety does not corroborate this, however. If system safety is to become more important, it must receive more support from the higher levels of management. The new AFSC Form 180 is a new development that is just beginning to take effect. The increasing technology will necessitate new, advanced types of hazard analysis techniques. The conclusion arrived at is that not only is system safety still developing, it may still be in its infancy.

Question 5b. This question sought to determine what trends are being perceived in the system safety discipline. Question nine of the system safety personnel interview and questions eight and nine of the program management personnel interview were used to answer this question. The issue of software system safety was raised by twenty-two percent of the system safety representatives. There is an increasing number of software-driven hardware that requires some kind of hazard analysis be done. MIL-STD-882B has a task for software hazard analysis, but there is a question as to how exactly to perform it. The System Safety Office at Armament Division has developed their own software hazard analysis technique, however, it is extremely manpower intensive and is currently limited in its application. This area is definitely one of concern. The Aeronautical Systems Division is currently concerned about their continuing loss of rated supplements. In a product division concerned mainly with buying aircraft, rated experience is invaluable. This trend has a great potential for degrading ASD's system safety support. System safety manpower in general is an area of concern for the program management community as well. A quarter of the program management personnel offering suggestions on how to improve system safety's contribution to their program said give them more people. This, of course, seems to be a panacea for all areas of acquisition. Unfortunately, in this time of tight budgets, the motto will probably continue to be "do more with less."

Recommendations

The following recommendations are made based on the responses to the structured interviews. In addition, the researcher's opinions are included based on his experience and analysis of the subject area.

1. Increased emphasis on system safety is needed at the higher management levels. To be effective, system safety personnel need to be allowed to do their jobs. If some kind of direction or even information about system safety from command level offices was disseminated, SPOs may be more receptive to accepting the suggestions of the system safety community. System safety representatives should solicit support from product division commanders, and two-letter directors.

2. A section on system safety should be included in the introductory level acquisition courses, such as Systems 100 and 200, which are offered by AFIT, and at the orientation classes given at each product division. This would expose new acquisition personnel to system safety very early and at least make them familiar with the purpose and concept of the discipline.

3. The Air Force Inspection and Safety Center should develop a computerized data base containing lessons learned and proven design criteria that can be used to avoid repeating mistakes. A program such as this could be used during design, source selection, and throughout full-scale development.

4. System safety managers need to be more involved with their programs to be able to effectively tailor their system safety programs to each system. This would help reduce unnecessary requirements and improve cost-

effectiveness, as well as improve relations with the SPO personnel.

Closing Remarks

In general, system safety seems to be effective and respected in the system acquisition process. An additional study should be conducted in two years to see what effects, if any, the AFSC Form 180 has on the perception of system safety. It would also determine whether or not there is an increase in emphasis on system safety occurring. Another area of research that would be worthwhile is in the area of promotion rates in system safety. If, in fact, fewer personnel get promoted in system safety, something needs to be done to change it. Systems Command needs to ensure that the people entering system safety are promotable and not being shoved into system safety to "get rid of them." Too many of these people tend to give the impression that system safety is a dead-end field where nobody gets promoted.

A research effort such as this thesis would be useful if it was conducted periodically to keep a finger on the pulse of system safety.

APPENDIX A

STRUCTURED INTERVIEW FOR SYSTEM SAFETY PERSONNEL

1) What is your current duty title?

2) What is your educational background?

3) How much experience do you have in system safety?

4) What system safety training have you had?

5) What programs do you currently have system safety responsibility for?

6) What office is your reporting official located in?

7) How would you describe your working relationship with the program office personnel you work with?

8) What are your views on the impact your system safety program has on your acquisition programs?

9) What trends are developing in the discipline of system safety?

APPENDIX B

STRUCTURED INTERVIEW FOR PROGRAM MANAGEMENT PERSONNEL

1) What is your current duty title?

2) What acquisition programs are you responsible for?

3) How familiar are you with the discipline of system safety?

4) Do you know who has system safety responsibility for your programs?

5) How do you view the discipline of system safety?

6) Does system safety contribute to your programs?

7) Is system safety cost-effective?

8) How could system safety be improved to enhance its value to your programs?

9) Have you received any guidance from higher headquarters concerning system safety?

Glossary

Hazard. A condition that is prerequisite to a mishap (6:2).

Hazardous Event. An occurrence that creates a hazard (6:2)

Hazard Probability. The aggregate probability of occurrence of the individual hazardous events that create a specific hazard (6:2).

Hazard Severity. An assessment of the worst credible mishap that could be caused by a specific hazard (6:2).

Implementing Command. The command or agency designated by HQ USAF to manage an acquisition program. Includes modification programs (2:11)

Managing Activity. The organizational element of DOD assigned acquisition management responsibility for the system, or prime or associate contractors or subcontractors who wish to impose system safety tasks on their suppliers (6:2).

Mishap. An unplanned event or series of events that results in death, injury, occupational illness, or damage to or loss of equipment or property (6:2).

Off-the-Shelf Item. An item determined by a material acquisition decision process review (DOD, Military Component, or subordinate organization as appropriate) to be available for acquisition to satisfy an approved material requirement with no expenditures of funds for development, modification, of improvement (6:2-3).

Risk. An expression of the possibility of a mishap in terms of hazard severity and hazard probability (6:3).

Safety. Freedom from those conditions that can cause death, injury, occupational illness, or damage to or loss of equipment or property (6:3).

Supporting Command. The command assigned responsibility for providing logistic support; it assumes program management responsibility from the implementing command (2:11).

System Safety. The application of engineering and management principles, criteria, and techniques to optimize safety within the constraints of operational effectiveness, time, and cost throughout all phases of the system life cycle (6:3).

System Safety Program. The combined tasks and activities of system safety management and system safety engineering that enhance operational effectiveness by satisfying the system safety requirements in a timely, cost-effective manner throughout all phases of the system life cycle (6:3).

System Safety Program Plan. A description of the planned methods to be used by the contractor to implement the tailored requirements of MIL-STD-882B, including organizational responsibilities, resources, methods of accomplishment, milestones, depth of effort, and integration with other program engineering and management activities and related systems (6:4).

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Box 19: Abstract

The purpose of this study was to explore the origin, evolution, and present status of system safety in the Air Force Systems Command (AFSC) acquisition process. The study had five objectives: 1) Determine the origin of system safety. 2) Describe the discipline of system safety. 3) Explain how system safety has evolved. 4) Determine the current effectiveness of system safety. 5) Determine what the future holds for system safety.

The study found that system safety was first applied to the Minuteman Missile Program in 1962. Since then, its scope has expanded and its governing documents have further specified responsibilities. The new AFSC Form 180 is required by the AFSC Supplement to AFR 800-16 to be filled out and signed by program managers. This form shows the residual risk associated with each hazard identified in a system and documents the program manager's acceptance of the residual risk. Thirty-five system safety personnel and thirty-five program management and engineering personnel from the four AFSC Product Divisions were interviewed to determine the current effectiveness of system safety. The study shows that system safety is considered an important part of the acquisition process and cost-effective. There is a need for improved software system safety in the future along with a continuing need for personnel.

Among recommendations of the study were soliciting emphasis on system safety from higher management levels, including system safety in introductory acquisition management courses, and development of a computerized lessons learned data base by the Air Force Inspection and Safety Center.

END